



INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁶ : B29C 47/12, 59/04, 47/88, G03B 35/00	A1	(11) International Publication Number: WO 99/12722 (43) International Publication Date: 18 March 1999 (18.03.99)
(21) International Application Number: PCT/US98/18717 (22) International Filing Date: 8 September 1998 (08.09.98) (30) Priority Data: 08/927,959 11 September 1997 (11.09.97) US (71)(72) Applicant and Inventor: MIKKELSEN, Øystein [NO/US]; 104 Bit Court, Kissimmee, FL 34743-6303 (US). (74) Agents: REGAN, Christopher, F. et al.; Allen, Dyer, Doppelt, Milbrath & Gilchrist, P.A., Suite 1401, 255 S. Orange Avenue, P.O. Box 3791, Orlando, FL 32802-3791 (US).		(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, HR, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG). Published <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i>
(54) Title: APPARATUS FOR FORMING A LENTICULAR SHEET AND ASSOCIATED METHODS <div data-bbox="418 1121 1175 1514" data-label="Diagram"> </div> (57) Abstract <p>An apparatus (40) for making a lenticular screen includes a rotating lenticular pattern forming roll (44) downstream from an extruder (41), and a conveyor belt (47) for pressing the hot plastic sheet (46) against the lenticular pattern forming roll (44) to form the lenticular pattern in the hot plastic sheet (46). The apparatus (44) preferably permits adjusting a tension of the conveyor belt (47) to thereby adjust a pressure applied to the hot plastic sheet (46), and permits adjusting a length of contact of the hot plastic sheet (46) around a periphery of the rotating lenticular pattern forming roll (44). The lenticular pattern forming roll (44) is preferably a chill roll for receiving a cooling fluid to cool the hot plastic sheet (46). The conveyor belt (47) may also be configured to include a flat portion (47a) downstream from the rotating lenticular pattern forming roll (44) for providing a flat surface during cooling of the hot plastic sheet (46). The apparatus (40) may include a frame carrying the lenticular pattern forming roll (44), a first belt support roll (57) positioned adjacent the lenticular pattern forming roll (44), and a second belt support roll (58) spaced from the first belt support roll (57). Accordingly, a positioner (61) may be associated with the second belt support roll (58) for adjusting a tension of the conveyor belt (47). A third belt support roll (63) may be positioned adjacent the lenticular pattern forming roll (44), and between the first and second belt support rolls (57, 58) and be positioned for adjusting a length of contact of the hot plastic sheet (46) around a periphery of the rotating lenticular pattern forming roll (44).</p>		

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**APPARATUS FOR FORMING A LENTICULAR SHEET
AND ASSOCIATED METHODS**
Field of the Invention

The present invention relates to the field of machinery and processes, and, more particularly, to an apparatus and methods for producing lenticular screens.

5 **Background of the Invention**

In lenticular imaging, an optical element called a lenticular screen is placed between an image and the viewer, as disclosed, for example, in U.S. Patent Nos. 3,504,059 to Glenn, Jr.; 2,724,312 to Gruetzner; and 3,683,773 to Dudley. Lenticular screens are typically formed from a transparent plastic sheet with lenses integrally formed on only one side that focus on the opposite and typically flat side. The lenticular elements can have many shapes, such as, for example, cylindrical, angular, spherical, or shaped like cube corners.

The original lenticular image can be created photographically, electronically or by a combination of both. Images can be reproduced and mass produced using photo-sensitive materials, printed by lithographic means or by other means of printing or transfer of inks or dyes. Electronic displays, such as cathode-tubes or flat panel displays, may also be fitted with a lenticular screen if the resolution of the display is sufficient.

One known technique for manufacturing lenticular screens includes cutting the lenticular lens pattern directly into transparent plastic materials. A lenticular screen can also be formed by the casting of thermosetting resins onto flat forms including the lenticular lens pattern. In addition, a lenticular screen may also be made by thermoforming a cast or extruded transparent sheet by heat and pressure between one polished plate and one plate with the lenticular pattern cut or engraved into its surface. Injection molding may also be used to form a lenticular screen.

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A lenticular screen may also be formed by extrusion of resin onto transparent pre-produced sheet or film, wherein the lenticular pattern is embossed into the resin by an embossing roll. The applied resin
5 may then be cured by radiation through the transparent material while the web is in contact with the embossing roller. Alternately, if the properties of the resin permit, the resin may be cured by radiation after the sheet has left the embossing roll.

10 A lenticular screen may also be manufactured using a machine similar to that normally used for flat sheet extrusion. As disclosed in U.S. Patent No. 2,724,312 to Gruetzner, for example, and as shown with reference to the prior art illustration of FIG. 1, such
15 a machine 20 includes a sheet extruder 21 and a polishing stack 22. The polishing stack 22 illustratively includes three rolls 23, 24 and 25, wherein the middle roll 24 has the lenticular pattern on its outer surface. The upper roll 23 and lower roll
20 25 have a smooth outer surface. A plurality of small rolls 27 support the sheet 26, and a pair of pull rolls 28 pull the sheet from the polishing stack 22. This type of machine 20 and associated method are used for most of the lenticular sheet produced at present.

25 The lenticular image can be reproduced on the photographic material and thereafter be laminated to the lenticular screen. There are also applications where the photographic emulsion is coated onto the flat side of the screen. The lenticular image can also be
30 printed with inks or dyes on a suitable material which, in turn, is laminated to the back of the screen or printed directly onto the flat side of the screen. Common for all the processes are that the lenticular image and the lenticular screen meet exacting
35 tolerances to obtain the desired result.

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The three roll polishing stack 22 is basically a simplified calendar. The polishing rolls 23, 24 and 25, are also known as chill rolls in flat plastic sheet production or as embossing rolls, if a pattern is cut or engraved into their surface. The functions of the rolls are to give the sheet, which initially is pre-formed by the sheet die at the end to the extruder 21, a more uniform gage, polish the sheet surface, transfer the pattern of the embossing roll to the sheet, and chill the material to a temperature lower than its softening point to keep the sheet in the shape formed by the rolls. The embodiment of the prior art machine 20' of FIG. 2 illustrates that the rolls 23', 24' and 25' can be arranged in a diagonal orientation. Of course a horizontal orientation is also possible.

Considering the arrangement of FIG. 1, if the three rolls in the stack 22 have one common motor drive, the upper roll 23 and middle roll 24 are held in position so they define a nip point therebetween. The lower roll 25 is held within a short distance to the middle roll 24, since the plastic is shrinking, and therefore the circumferential speed of the rolls needs to be differentiated. The plastic web 26 is taken away by the pull rolls 28 to keep the sheet in relative contact with the surface of the middle and lower rolls, but will also apply extra tension to the plastic web 26 as well. The tension caused by the pull rolls 28 will stretch the material.

In the case of individual drives for each of the rolls in the stack 22' shown in FIG. 2, the upper roll 23' can also form a nip with the middle roll 24'; however, its speed has to be slightly different to keep the plastic web 26' in contact with the middle roll. In addition, pull rolls, not shown, still have the task

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of keeping the plastic in contact with the upper roll 23'.

Unfortunately, in the prior art machines 20, 20' the sheet is held under pressure just in the nip 5 between the first two rollers, and it is there that the lenticular lenses are created. The time the plastic sheet is under pressure in the nip will depend on the diameter of the rolls, the speed of the web and the thickness of the material. Even with larger diameter 10 rolls, a thicker sheet, and at the speeds somewhat less than recommended to ensure proper flow through the extruder, the time period is relatively short. In fact, the time period is often too short to ensure proper reproduction of the lenticular pattern onto the 15 plastic web. Downstream from this nip point, only the tensioning of the sheet enables contact of the sheet with the embossing roll. Of course, the contact is limited by the tension that can be applied to the still hot plastic either by the upper roll 23' (FIG. 2) or by 20 the pull rolls 28 (FIG. 1).

The tensioning of the sheet can, for some materials that otherwise are suited for lenticular screens, cause a haze and/or make the sheet brittle. Excessive tensioning can result in stress that can be 25 released even at temperatures lower than the softening point and cause the sheet to buckle. It is required, if the finished lenticular screen is to be optically acceptable, that the lenticular lenses in the plastic material replicate the pattern on the embossing roller 30 as closely as possible.

In addition, the energy carried in the plastic sheet will have a significant negative effect on the valleys between adjacent lenses, and also on the lens curvature. Even with a relatively thin sheet, for 35 example, having a thickness of about 0.4 mm, it can be difficult in a conventional polishing stack to obtain

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an accurate reproduction of the lens pattern. The thicker the sheet, the greater the problem with accurately reproducing the lenticular pattern. Some materials can, if cooled too quickly, leave a residue
5 on the rolls, which if allowed to build up, would prevent the lenticular pattern from being accurately reproduced in the plastic. Accordingly, the machine is taken out of service and the residue removed, thereby resulting in a loss of production.

10 Summary of the Invention

In view of the foregoing background, it is therefore an object of the invention to provide an apparatus and associated method for efficiently and accurately making a lenticular screen, and while
15 accounting for shrinkage and other properties of the plastic material.

This and other objects, advantages, and features of the present invention are provided by an apparatus for making a lenticular screen comprising a
20 rotating lenticular pattern forming roll downstream from an extruder, and a conveyor belt for pressing the hot plastic sheet against the lenticular pattern forming roll to form the lenticular pattern in the hot plastic sheet. The apparatus preferably includes
25 tension adjusting means for adjusting a tension of the conveyor belt to thereby adjust a pressure applied to the hot plastic sheet. In addition, the apparatus preferably further comprises contact adjusting means cooperating with the conveyor belt for adjusting a
30 length of contact of the hot plastic sheet around a periphery of the rotating lenticular pattern forming roll. Accordingly, the dwell time of the hot plastic sheet on the lenticular pattern forming roll can be controlled, along with the pressure applied to the hot
35 plastic sheet.

Other aspects of the present invention relate to cooling of the plastic sheet after the lenticular

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pattern has been formed. The lenticular pattern forming roll is preferably a chill roll for receiving a cooling fluid therethrough to cool the hot plastic sheet. The conveyor belt may also be configured to

5 include a flat portion downstream from the rotating lenticular pattern forming roll. Accordingly, the flat conveyor belt portion provides a flat surface during secondary cooling of the hot plastic sheet after the lenticular pattern is formed and allows for material

10 shrinkage. Cooling means may also be positioned adjacent the flat portion of the conveyor belt for further cooling the hot plastic sheet, and/or the belt and sheet.

Also relating to handling of the sheet during

15 cooling, the apparatus may include at least one passive sheet guide roll positioned opposite the conveyor and downstream from the lenticular pattern forming roll to guide the hot plastic sheet on the conveyor belt without imparting tension to the sheet. In other

20 words, pull rolls are not used which have a tendency to stress the plastic material.

The apparatus may include a frame carrying the lenticular pattern forming roll, a first belt support roll positioned adjacent the lenticular pattern forming

25 roll, and a second belt support roll spaced from the first belt support roll. Accordingly, a positioner may be associated with the second belt support roll, for example, for adjusting a tension of the conveyor belt.

The apparatus may also include a third belt

30 support roll carried by the frame and positioned adjacent the lenticular pattern forming roll and between the first and second belt support rolls. Accordingly, a positioner may be associated with the third belt support roll for adjusting a length of

35 contact of the hot plastic sheet around a periphery of the rotating lenticular pattern forming roll. In other words, control of the third roll provides one

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embodiment for adjusting the contact time of the hot plastic sheet on the lenticular pattern forming roll. One or more additional bearings may be provided to press the underside of the belt and thereby press the plastic sheet against the lenticular pattern forming roll. In addition, the second and third belt support rolls are also preferably arranged to define the flat portion of the conveyor belt downstream from the rotating lenticular pattern forming roll, and the flat portion may be horizontally oriented.

The conveyor belt itself preferably has a relatively smooth surface to thereby form a corresponding smooth surface on the reverse side of the plastic sheet. In one embodiment, the conveyor belt may comprise a metal fabric. One or more brushes may be positioned to clean the surface of the belt.

A method aspect of the present invention is for making a screen having a predetermined pattern thereon, such as for making a lenticular pattern when using a lenticular pattern forming roll. The method preferably comprises the steps of: extruding a hot plastic sheet; positioning a rotating pattern forming roll downstream from the extruder; and using a conveyor belt for pressing the hot plastic sheet from the extruder against the pattern forming roll to form a pattern in the hot plastic sheet.

The method also preferably further comprises the steps of: adjusting a tension of the conveyor belt to thereby adjust a pressure applied to the hot plastic sheet, and/or adjusting a length of contact of the hot plastic sheet around a periphery of the rotating pattern forming roll. The method may also include the step of configuring the conveyor belt to include a flat portion downstream from the rotating pattern forming roll and providing a flat surface during cooling of the hot plastic sheet after the pattern is formed therein.

Brief Description of the Drawings

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FIG. 1 is a schematic side cross-sectional view of an embodiment of an apparatus for making a lenticular screen in accordance with the prior art.

FIG. 2 is a schematic side cross-sectional view of another embodiment of an apparatus for making a lenticular screen in accordance with the prior art.

FIG. 3 is a perspective view of an apparatus for making a lenticular screen in accordance with the present invention.

FIG. 4 is a schematic side cross-sectional view of the apparatus as shown in FIG. 3 with several additional details being illustrated.

FIG. 5 is a greatly enlarged cross-sectional view of the entry contact area of the plastic sheet with the lenticular pattern forming roll and conveyor belt in the apparatus as shown in FIG. 3.

FIG. 6 is a greatly enlarged cross-sectional view of the exit contact area of the plastic sheet with the lenticular pattern forming roll and conveyor belt in the apparatus as shown in FIG. 3.

FIG. 7 is a greatly enlarged cross-sectional view of the area where the conveyor belt and plastic sheet leave the lenticular pattern forming roll area in the apparatus as shown in FIG. 3.

FIG. 8A is a perspective view of a mandrel for forming a lenticular pattern forming roll in accordance with a method of the present invention.

FIG. 8B is a perspective view of the mandrel with a metal layer deposited thereon in accordance with the present invention.

FIG. 8C is a perspective view of the mandrel and metal layer deposited thereon wherein a lenticular pattern is being formed to define a lenticular sleeve in accordance with the present invention.

FIG. 8D is a perspective view of the mandrel and lenticular sleeve illustrating removal of the

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sleeve from the mandrel in accordance with the present invention.

FIG. 8E is a perspective view of the lenticular sleeve being installed onto a chill roll in accordance with the present invention.

FIG. 9 is a flowchart of the method steps for making the lenticular pattern forming roll in accordance with the present invention.

FIGS. 10A-10D are cross-sectional views illustrating conversion of the lenticular sleeve into a flat lenticular form in accordance with the invention.

Detailed Description of the Preferred Embodiments

The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Thicknesses of layers are exaggerated for clarity. Like numbers refer to like elements throughout.

Referring initially to FIGS. 3-7, the apparatus for making a lenticular screen is first described. The apparatus 40 includes a rotating lenticular pattern forming roll 44 downstream from an extruder 41, and a conveyor belt 47 for pressing the hot plastic sheet 46 against the lenticular pattern forming roll to thereby form the lenticular pattern in the hot plastic sheet. The apparatus 40 preferably includes tension adjusting means for adjusting a tension of the conveyor belt 47 to thereby adjust a pressure applied to the hot plastic sheet. In addition, the apparatus 40 preferably further comprises contact adjusting means cooperating

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with the conveyor belt for adjusting a length of contact of the hot plastic sheet 46 around a periphery of the rotating lenticular pattern forming roll 44.

Accordingly, the dwell time of the hot plastic sheet 46

5 on the lenticular pattern forming roll 44 can be controlled, along with the pressure applied to the hot plastic sheet. The pressure and dwell time provide an improved quality of the reproduction of the lenticular pattern in the plastic sheet 46. In addition, the

10 dwell time can be longer or shorter depending on the properties of the plastic material, its thickness, the pattern to be transferred, and the desired speed of the plastic sheet as would be readily understood by those skilled in the art.

15 As shown in the illustrated embodiment, the lenticular pattern forming roll 44 is preferably a chill roll for receiving a cooling fluid therethrough to cool the hot plastic sheet 46. The cooling fluid may be a liquid, such as water, for example, or may be
20 a gas as would be readily appreciated by those skilled in the art. The cooling fluid is supplied by the schematically illustrated cooling fluid source 50.

The conveyor belt 47 may also be configured to include a flat portion 47a downstream from the rotating
25 lenticular pattern forming roll 44 as perhaps best shown in FIGS. 3 and 4. Accordingly, the flat conveyor belt portion 47a provides a flat surface during secondary cooling of the hot plastic sheet 46 after the lenticular pattern is formed and readily allows for
30 material shrinkage without imparting undesirable stress to the plastic. Cooling means may also be positioned adjacent the flat portion 47a of the conveyor belt for further cooling the hot plastic sheet 46, and/or the belt and sheet. In the illustrated embodiment, an

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upper cooler 52a may direct cooling air onto the plastic sheet 46, and while the lower cooler directs air upward onto the back side of the conveyor belt 47 as would be readily understood by those skilled in the art. The air coolers could be replaced by water or other heat exchangers as would be understood by those skilled in the art. The time/temperature profile of cooling may be thus readily controlled to ensure a high quality lenticular screen.

Also relating to handling of the sheet 46 during cooling, the apparatus 40 illustratively includes at least one passive sheet guide roll 53 positioned opposite the conveyor belt 47 and downstream from the lenticular pattern forming roll 44 to guide the hot plastic sheet on the conveyor belt without imparting undesirable tension to the sheet, in contrast to the conventional puller rolls 28 (FIG. 1). The illustrated passive guide roll 53 is a rubber coated roll, although those of skill in the art will recognize that other types and compositions of rolls may also be used. The passive guide roll 53 may be positioned by a positioner 54, such as may be provided by swing-arms and pneumatic cylinders, or other arrangements with linear motion and hydraulics or mechanical positioning as would be readily understood by those skilled in the art. The passive guide roll 53 is positioned over the second belt support roll 58 so that the sheet 46 is pulled from the apparatus 40 along a line parallel to the flat conveyor belt portion 47a. The passive guide roll 53 is only driven by the friction between itself, the plastic sheet 46 and the belt 47. Pressure on the passive guide roll 53, to ensure sufficient friction, can be applied mechanically or by pneumatic or

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hydraulic cylinders as would be readily understood by those skilled in the art.

The pull caused by the passive guide roll 53, which is only driven by the friction between itself, the plastic sheet 46 and the belt 47 passing over the second belt support roll 58, will not cause as much tension as a conventional set of pull rolls. Accordingly, it will also be easier to keep control of the distances in the lenticular pattern, like the pitch of the lenticular lenses. Some tension will be imparted because the plastic sheet 46 will have a higher expansion coefficient than the material in the belt 47. Since the lenticular screen is a finished product as far as the plastic is concerned, less stress is preferred as would be readily understood by those skilled in the art.

The apparatus 40 includes a frame 55 (FIG. 4) carrying the lenticular pattern forming roll 44, a first belt support roll 57 positioned adjacent the lenticular pattern forming roll, and a second belt support roll 58 spaced from the first belt support roll. The first belt support roll 57 is illustratively fixed, but could be mounted such as to be movable. For example, the first belt support roll 57 could also be mounted to move horizontally to give sufficient distance in front of the nip with the lenticular pattern forming roll 44 so that a plastic web could be entered for extrusion coating with tie-layers and resin, or only resin, and which thereafter is contacted by the lenticular pattern forming roll.

A positioner 61 may be associated with the second belt support roll 58 for adjusting a tension of the conveyor belt 47 as would be readily appreciated by those skilled in the art. For example, the positioner

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61 may be hydraulic, pneumatic, or electrically operated as would be understood by those skilled in the art without further explanation herein.

The apparatus 40 also illustratively includes a
5 third belt support roll 63 carried by the frame 55 and positioned adjacent the lenticular pattern forming roll 44 and between the first and second belt support rolls 57, 58, respectively. Accordingly, another positioner
10 65 may be associated with the third belt support roll 63 for adjusting a length of contact of the hot plastic sheet 46 around a periphery of the rotating lenticular pattern forming roll 44. The positioner 65 may include swing arms and motorized screws, but mechanical guides like curved or straight linear guides and other
15 mechanical means for positioning that provide the same functions are also contemplated by the present invention. Considered in somewhat different terms, control of the position of third roll 63 provides one embodiment for adjusting the contact time and extent of
20 the hot plastic sheet 46 on the lenticular pattern forming roll 44. Those of skill in the art will appreciate that the relative positioning of the first belt support roll 57, the lenticular pattern forming roll 44, and the third roll 63 define the contact of
25 the hot plastic sheet 46 with the lenticular pattern forming roll.

One or more additional bearings 67 may be provided to press the underside of the conveyor belt 47 and thereby press the plastic sheet 46 against the
30 lenticular pattern forming roll 44 (FIG. 4). For special applications where continued high pressure higher than the tensioning of the belt 47 can apply, an arrangement with needles, such as needle bearings, may

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be positioned between the conveyor belt and a pad or several pads, not shown, as wide as the belt, but relatively short in the machine direction, onto which pressure can be applied by hydraulic cylinders as would
5 also be understood by those skilled in the art.

In addition, the second and third belt support rolls 58, 63 are also preferably arranged to define the flat conveyor belt portion 47a downstream from the rotating lenticular pattern forming roll 44, and the
10 flat portion may be horizontally oriented as shown in the illustrated embodiment. In other embodiments, the roll may be oriented so that the flat conveyor portion 47a is at other angles as will be readily appreciated by those skilled in the art.

15 The conveyor belt 47 itself preferably has a relatively smooth surface to thereby form a correspondingly smooth surface on the reverse side of the plastic sheet 46. In one embodiment, the conveyor belt 47 may comprise a metal fabric, such as formed of
20 stainless steel or titanium, for example, and as would be readily appreciated by those skilled in the art. The conveyor belt 47 is preferably seamless and continuous with sufficient hardness and strength for carrying the plastic sheet 46 and applying the desired
25 pressure thereto as would be understood by those skilled in the art. Polished, hard and corrosion resistant belts are today used in other industrial processes like wood chip board production, for example, and are therefore readily available.

30 One or more brushes 71 may be positioned to clean the surface of the belt 47 as would also be readily appreciated by those skilled in the art. A vacuum arrangement, not shown, may also cooperate with the brush 71 to clean the belt 47. The length of the
35 belt 47, if kept clean will ensure a relatively long

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life compared to conventional polishing rolls, for example.

Some or all of the rolls 44, 57, 58 and 63 may be driven by electric motors 72, 73, 74 and 75, respectively, as schematically illustrated in FIG. 4. In other embodiments, some of the rolls may be passively driven as will also be readily appreciated by those skilled in the art. As depicted in the illustrated embodiment, a positioner 77 may be operatively connected to the lenticular pattern forming roll 44 to control its relatively position, such as to move it between engaged and retracted positions. The positioner 77 may include swing arms and associated hydraulic cylinders, for example, but other arrangements with linear guides, and/or pneumatic or mechanical positioning are also contemplated by the present invention.

The outer surfaces of the rolls 57, 58 and 63 may preferably be hardened for durability. These rolls are desirably ground parallel within the tolerances normal for the plastic extrusion industry, but do not necessarily need to have a fine surface as provided by polishing. Instead, their surface roughness will somewhat depend on the hardness and thickness of the belt 47. The rolls 57, 58 and 63 and any other rolls that will be in contact with the back of the belt 47 will be cheaper to manufacture, because they do not need the true mirror surface required in conventional polishing stacks. For enhanced friction, the first and second belt support rolls 57, 58 and/or the third belt support roll 63 may be coated with a hard polyurethane rubber or other appropriate rubber material.

The apparatus 40 offers a number of important advantages including easy start-up, since no supporting reproduced sheet has to be thread trough the machine

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prior to starting the extruder 41. With the lenticular pattern forming roll 44 in a retracted position and with the belt 47 tensioned, one can start extruding onto the belt over the first belt support roll 57 and
5 when the flow is even enough, the lenticular pattern forming roll 44 may be moved into the engaged position along with appropriate repositioning of the second and third belt support rolls 58, 63.

The nip between the lenticular pattern forming
10 roll 44 and the first belt support roll 57 with the belt 47 function as the beginning of the nip, and, thereafter, the belt ensures proper holding and pressure for the plastic sheet 46. The enclosed almost chamber-like arrangement for the plastic sheet 46 is
15 kept for an adjustable period after entering the nip and improves the reproduction of the pattern, minimizes local gage variations, and gives better control of the cooling of the sheet. The line speed can be faster and allow for a higher production rate than would be
20 otherwise possible given the same thickness and kind of material being processed using a conventional polishing stack.

One method aspect of the present invention is for making a screen having a predetermined pattern
25 thereon, such as for making a lenticular pattern when using a lenticular pattern forming roll 44. The method preferably comprises the steps of: extruding a hot plastic sheet 46; positioning a rotating pattern forming roll 44 downstream from the extruder 41; and
30 using a conveyor belt 47 for pressing the hot plastic sheet from the extruder against the pattern forming roll to form a pattern in the hot plastic sheet.

The method also preferably further comprises the steps of: adjusting a tension of the conveyor belt

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47 to thereby adjust a pressure applied to the hot plastic sheet 46, and/or adjusting a length of contact of the hot plastic sheet around a periphery of the rotating pattern forming roll 44. The method may also
5 include the step of configuring the conveyor belt to include a flat portion 47a downstream from the rotating pattern forming roll and providing a flat surface during cooling of the hot plastic sheet 46 after the pattern is formed therein. Accordingly, the plastic
10 sheet 46 may be formed to be relatively flat as is desirable for many applications.

Referring now more particularly to FIGS. 5-7 another aspect of the invention is explained. The first belt support roll 57 may be a chill roll
15 comprising a tubular body 57a through which the cooling fluid is passed. In addition, the third belt support roll 63 may also be a chill roll comprising a tubular body 63a through which cooling fluid is also passed as would be readily understood by those skilled in the
20 art. Of course, in other embodiments either or both of these rolls may not need the cooling fluid.

As shown in FIGS. 5 and 6, the lenticular pattern forming roll 44 may comprise a tubular body defining a chill roll 44a and a lenticular sleeve 44b
25 positioned on the chill roll. The lenticular sleeve 44b has a lenticular pattern formed on an outer surface for forming the corresponding lenticular pattern in the plastic sheet 46. The sleeve 44b may be readily manufactured and transported to a desired location to
30 be installed on the chill roll 44a. The lenticular sleeve 44b may also be removed from the chill roll 44a and transported for resurfacing and without requiring transporting of the entire chill roll. Accordingly, considerable savings may be realized. In addition, a

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spare sleeve 44b may be maintained in inventory in the manufacturing facility to thereby reduce downtime as would be readily understood by those skilled in the art.

5 The lenticular sleeve 44b may preferably comprise a nickel-phosphorous composition defining at least a radially outermost portion of the sleeve in which the lenticular pattern is formed. More particularly, the nickel-phosphorous composition is
10 preferably an amorphous nickel-phosphorous composition comprising nickel in a range of about 75 to 86 percent by weight, and phosphorous in a range of about 14 to 25 percent by weight. This material is durable in use, yet the lenticular pattern is readily formed in the
15 composition using conventional diamond cutting techniques as will be described in greater detail below. As would be readily understood by those skilled in the art, the nickel-phosphorous composition may be formed by electrodepositing or electroless depositing,
20 for example.

 The interior surface of the lenticular sleeve 44b may have a predetermined diameter to frictionally engage an adjacent exterior surface of the chill roll 44a. The interior surface of the lenticular sleeve 44b
25 may also have a predetermined surface roughness to frictionally engage the adjacent exterior surface of the chill roll 44a. When using the nickel-phosphorous composition, the interior surface of the lenticular sleeve 44a may preferably have a coefficient of
30 friction of at least about 0.1.

 One method aspect of the invention is for making a lenticular pattern forming roll 44 for forming a lenticular screen as is explained with reference to FIGS. 8A-8E and the flowchart 90 of FIG. 9. From the
35 start at Block 92, the outer surface of a mandrel 80 is

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prepared, such as by polishing to define a desired surface (FIG. 8A). The amorphous nickel-phosphorous metal layer 81 is deposited onto the mandrel 80 using either an electroless or electrodeposition technique as would be readily appreciated by those skilled in the art. At Block 98 and as shown schematically in FIG. 8C, the lenticular pattern is cut into the outer surface of the metal layer 81 by the illustrated diamond cutter 84 while on the mandrel 80 to form the lenticular sleeve 44b. At Block 100, the thus formed lenticular sleeve 44b is removed or freed from the mandrel as shown in FIG. 8D. The lenticular sleeve 44b may be freed from the mandrel 80 by the injection of air or another fluid into the interface between the sleeve and mandrel. Alternately, a difference in coefficients of thermal expansion may be used to separate the sleeve and mandrel as would be readily appreciated by those skilled in the art. In other words, cooling or heating may be used to separate the sleeve 44b from the mandrel 80.

The lenticular sleeve 44b may typically be shipped to the location making the lenticular screen as set forth in Block 102. Because of the relatively high cost of the capital equipment for forming the lenticular pattern, the forming or a similar refinishing process is likely to only be performed at certain locations suitably equipped as would be understood by those skilled in the art. The lenticular sleeve 44b may be installed onto the chill roll 44a (Block 104) as shown in FIG. 8E before the process ends (Block 106).

The step of installing the lenticular sleeve 44b onto the chill roll 44a may also be aided by the injection of air or other fluid into the interface

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between the sleeve and chill roll. Alternately, heating may be used to first expand the sleeve prior to positioning on the chill roll. Of course, the sleeve 44b may also be removed from the chill roll to

- 5 facilitate changing to a new lenticular pattern or to permit refinishing of the lenticular sleeve 44b as would be appreciated by those skilled in the art.

The lenticular sleeve 44b can also be secured to the chill roll 44a using a hot-melt adhesive, for
10 example, and with a suitable melting point so that the sleeve will not separate when being used for forming the lenticular screen as will be readily appreciated by those skilled in the art. Another form of an adhesive bond may be provided by a low melting temperature
15 solder metal or alloy applied to one or both of the outer surface of the chill roll 44a and the inner surface of the sleeve 44b. By heating the sleeve and roll assembly to the appropriate temperature and keeping the sleeve 44b in the proper position while
20 cooling the assembly below the melting point of the adhesive or solder, the sleeve can be fixed to the chill roll 44a with very high strength. In both examples, of course, the sleeve can be removed by reheating the assembly to the appropriate melting
25 temperature as would be readily understood by those skilled in the art.

Nickel alloys may be especially suitable for cutting using single crystal diamond. Adequate machinery for cutting in an amorphous nickel-
30 phosphorous composition with properly prepared single crystal diamonds can allow for a relatively large area with a surface roughness of less than RMS 10Å. Cutting of optical surfaces and forms with single crystal diamonds is relatively well known by those skilled in
35 the art, and requires no further discussion herein.

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The inventor of the present invention previously developed chemistry and methods for making relatively thick deposits (50 to 500 micron) of amorphous nickel-phosphorous with 13 to 15% phosphorous content (by weight) by electroless depositing. At present, amorphous nickel-phosphorous compositions with even higher phosphorous content can also be deposited by electrodepositing as would be readily understood by those skilled in the art. Although the mechanism is not entirely understood, tool wear is minimized when the phosphorus content of the deposit is greater than about 11% (by weight). Accordingly, the nickel-phosphorous has good lubricating properties which makes it well suited for tools used in the forming of plastics.

Both the electroless and electrodeposited nickel-phosphorous alloys can be used for the lenticular sleeve 44b, but the electrodeposited may have some advantages. Electrodeposition may be at a rate of up to 60 microns per hour and a phosphorous content of higher than about 15% can be obtained. Another advantage of the electrodeposited nickel-phosphorous composition is the consistently higher density as compared to the electroless deposited material. It is believed without applicant being bound thereto that the electrodeposited nickel-phosphorous alloys contain a lower void volume than the electroless deposited alloys, that is, the nickel and phosphorous are more closely packed. This reduces the porosity in the plated deposit and is of particular interest for diamond machining applications since it potentially leads to fewer micro defects in the material being machined, thereby resulting in improved surface finish. In addition, electrodeposited Ni-P can have a hardness of Rockwell C 45-51 as deposited, and by heat treatment can reach a hardness of Rockwell C 70-72. This

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hardness range is sufficient to obtain a lenticular sleeve 44b with a relatively long service life.

There are several configurations of the lenticular pattern forming roll 44 including the lenticular sleeve 44b. For example, a cylindrical sleeve portion may be produced by depositing 100% nickel onto the mandrel 80, depositing required thickness of nickel-phosphorous alloy and cutting the lenticular pattern into the outer layer with diamonds. Of course, the entire sleeve 44b may be formed either by the electroless depositing or electrodepositing of the nickel-phosphorous onto the mandrel 80, and thereafter the sleeve is given a lenticular pattern by cutting with diamonds.

In other embodiments, a base portion of the sleeve 44b may be produced by electrodepositing the nickel-phosphorous onto the mandrel 80, another metal or metal alloy suited for cutting with diamonds is deposited onto the base portion, and the lenticular pattern is cut into the other metal or alloy with diamonds. Similarly, the base portion of the sleeve 44b may be produced by electrodepositing nickel onto the mandrel 80, another metal or metal alloy suited for cutting with diamonds is deposited onto the base portion, and the lenticular pattern is cut into the other metal or alloy with diamonds.

In yet another embodiment, a cylindrical sleeve for fitting by expansion onto a suitable roll is produced by hot or cold rolling from a ring produced by casting and/or machining of a metal or alloy suited for cutting with diamonds. Alternately, the metal or alloy suited for cutting with diamonds is deposited onto the underlying cylindrical sleeve, thereafter the lenticular pattern is cut in the outer surface with diamonds.

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According to another aspect of the invention and as shown with additional reference to FIGS. 10A-10D, the lenticular sleeve 44b (FIG. 10A) can be split or cut axially to produce the structure 44b' shown in FIG. 10B, then straightened to the intermediate structure 44" shown in FIG. 10C, to finally become a flat form structure 44''' as shown in FIG. 10D to be used for casting, injection molding or thermoforming of lenticular screens. Flat lenticular forms have traditionally been cut into sheets, which can be both difficult and costly. In contrast, the axial splitting of the lenticular sleeve 44b in accordance with the invention can provide a flat lenticular form 44''' relatively easily and economically.

As long as the outer or mantel surface of the chill roll 44a, to be used with the lenticular sleeve 44b is not damaged in any way, the roll itself need not be resurfaced when the lenticular sleeve is exchanged. Many different lenticular screens are commonly desired and the ability to reuse the same chill roll 44a (or a pair for speedy exchange) enable more economical production of shorter runs, and allow for special lenticular lenses, as compared to dedicated rolls with the lenticular pattern in the outer surface. The cutting of the lenticular pattern may also take place on extremely accurate machines in accordance with the invention. The lenticular sleeve 44b enables less weight to be manipulated during cutting as would be readily appreciated by those skilled in the art. Less weight to be handled during cutting results in one or both of easier cutting and higher accuracy.

The following table, formulas, derivations and calculations show that it is possible for the nickel-phosphorous lenticular sleeve 44b to be fitted onto a chill roll 44a to produce a lenticular pattern forming

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roll 44 that can fill the requirements for use in production of plastic sheet and film:

The properties of the electrodeposited Ni-P are as follows:

5	<u>Properties:</u>	<u>Typical Value:</u>
	Composition	75-86% N:, 14-25% P
	Coefficient of Friction	0.13
	Corrosion Resistance	1000+ hours @ .001"
	Neutral Salt Spray	500 hours @ .0003"
10	(ASTM B-117)	
	Copper Accelerated Salt Spray	200+ hours @ .0003"
	CASS (ASTM B-368)	
	RCA Nitric Acid Test	Unlimited exposure without attack
15	Thickness Constraints	None
	Hardness	
	• As Deposited	Rockwell C 45-51
	• Bake 590° F/3 hours	Rockwell C 63-66
	• Bake 750° F/1 hour	Rockwell C 70-72
20	Melting Point	1630° F
	Density	7.6 g/cm ³ (0.27 pounds/inch ³)
	Internal Stress	None
	Tensile strength	
	• As Deposited	~100 KSI
25	• Heat Treated	~270 KSI
	Ductility	
	• per ASTM Bend Test	10% - 15% elongation typ.
	Wear Resistance	Comparable to Hard Chrome

At 20°C, the roll diameter is D, and at temperature t, the roll diameter can be found from $D_t = D(1 + \Delta T \text{ Coer})$, and $\Delta T = t - 20$, where Coer is expansion coefficient of steel. A pull of 5,000 N (maximum) is needed for most of the known plastic materials when produced in a polishing stack or calendar. At temperature t, the sleeve 44b should apply a pressure of P_t to clamp sufficiently around the chill roll 44a for adequate friction between the sleeve

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and the chill roll. P_t is given below and where L is length of the sleeve, and f is coefficient of friction between the sleeve and the chill roll:

$$P_t = \frac{5,000/f}{\pi D t \cdot L} \approx \frac{5,000}{\pi D L f} \quad <1>$$

$$2N_{max} = \int_0^\pi P_t L \cdot \frac{D t}{2} \cdot \sin \alpha \cdot d\alpha \quad <2>$$

$$= D t \cdot L \cdot P_t$$

At temperature t , the maximum stress in the sleeve will be (P_t is also imparting stress to the sleeve, but that is small enough to be neglected) and t_m is the thickness of Ni-P sleeve:

$$\sigma_{max}(t) = \frac{N_{max}}{L \cdot t_m} = \frac{5,000}{2\pi f \cdot L \cdot t_m}$$

Supposing now that the inside diameter of the sleeve at temperature t is d_t , (when it is free), then the mean diameter will be $d_t + t_m$. Under a stress of σ_{max} the sleeve will expand to an inside diameter of D_t , and a mean diameter of $D_t + t_m$. The expanded length is, where E is Young's modulus of the sleeve:

$$\Delta L_t = \pi(D_t + t_m) - \pi(d_t + t_m) \\ = \pi(D_t - d_t)$$

but:

$$\Delta L_t = \pi[(D - d) + \Delta T(D \cdot \text{Coer} - d \cdot \text{Coes})] \\ L_t = \pi(d_t + t_m) \\ = \pi[d(1 + \Delta T \text{Coes}) + t_m]$$

$$\frac{D - d + \Delta T(D \cdot \text{Coer} - d \cdot \text{Coes})}{d(1 + \Delta T \text{Coes}) + t_m} = \frac{5,000}{2\pi f \cdot L \cdot t_m E}$$

From the above equations, we can find the value of d . The pressure needed to expand the sleeve from an inside diameter of $D + \delta$ at 20°C :

$$\Delta L = \pi(D + \delta - d)$$

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$$L = \pi (d + tm)$$

δ is the gap needed for safely fitting the sleeve onto the chill roll.

$$\begin{aligned} \Delta L / L &= \sigma / E \\ \sigma &= \Delta L E / L = \frac{(D + \delta - d) E}{d + tm} \end{aligned}$$

$$\frac{(D + \delta) P}{2tm} = \frac{(D + \delta - d) E}{d + tm}$$

and wherein P is the air pressure needed to expand the sleeve.

Accordingly, the following table is based upon using the above equations and the following parameters: D=900mm, E= 2 x10⁵ Mpa, T=25 degrees Celsius (That is t=45 degrees Celsius, for ample applications), L=800mm, f=0.1, and $\delta=0.1$.

	tm (mm)	d (mm)	P (N/mm ²)	(N/mm ²)
	0.15	899.657	0.0328	98.4
	0.20	899.731	0.0364	81.9
20	0.25	899.776	0.040	72.0
	0.30	899.806	0.044	66.0
	0.35	899.827	0.047	60.4
	0.40	899.843	0.051	57.4
	0.45	899.856	0.054	54.0
25	0.50	899.865	0.058	52.2

The stress inside the nickel-phosphorous sleeve σ is always much less than the tensile strength, that is, $\sigma_b=100$ KSI ~270 KSI, ie, $\sigma_b = 689.5$ N/mm² ~1861.6 N/mm².

The apparatus 40 and the process can also be used for improved embossing of other kinds of patterns or even for reproduction of shallow forms into plastic sheets which in a secondary operation can be die-cut into single elements, for example. Accordingly, many modifications and other embodiments of the invention will come to the mind of one skilled in the art having the benefit of the teachings presented in the foregoing

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descriptions and the associated drawings. Therefore,
it is to be understood that the invention is not to be
limited to the specific embodiments disclosed, and that
modifications and embodiments are intended to be
5 included within the scope of the appended claims.

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THAT WHICH IS CLAIMED IS:

1. An apparatus for making a lenticular screen comprising:
an extruder¹ for extruding a hot plastic sheet;
5 a rotating lenticular pattern forming roll downstream from said extruder; and
a conveyor belt for pressing the hot plastic sheet against said lenticular pattern forming roll to form a lenticular pattern in the hot plastic sheet and
10 defining the lenticular screen.
2. An apparatus according to Claim 1 further comprising tension adjusting means for adjusting a tension of said conveyor belt to thereby adjust a pressure applied to the hot plastic sheet.
- 15 3. An apparatus according to Claim 1 further comprising contact adjusting means cooperating with said conveyor belt for adjusting a length of contact of the hot plastic sheet around a periphery of said rotating lenticular pattern forming roll.
- 20 4. An apparatus according to Claim 1 wherein said conveyor belt comprises a flat portion downstream from said rotating lenticular pattern forming roll and providing a flat surface during cooling of the hot plastic sheet after the lenticular pattern is formed
25 therein.
5. An apparatus according to Claim 4 further comprising cooling means positioned adjacent said flat portion of said conveyor belt for cooling the hot plastic sheet after the lenticular pattern is formed
30 therein.
6. An apparatus according to Claim 1 wherein said lenticular pattern forming roll comprises means for receiving a cooling fluid therein to cool the hot plastic sheet.
- 35 7. An apparatus according to Claim 1 further comprising at least one passive sheet guide roll positioned opposite said conveyor and downstream from

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said lenticular pattern forming roll to guide the hot plastic sheet on said conveyor belt after the lenticular pattern is formed therein and without imparting tension thereto.

5 8. An apparatus according to Claim 1 further comprising:

 a frame carrying said lenticular pattern forming roll;

 a first belt support roll carried by said frame
10 and positioned adjacent said lenticular pattern forming roll; and

 a second belt support roll carried by said frame and spaced from said first belt support roll.

 9. An apparatus according to Claim 8 further
15 comprising a positioner associated with said second belt support roll for adjusting a tension of said conveyor belt.

 10. An apparatus according to Claim 8 further comprising:

20 a third belt support roll carried by said frame and positioned adjacent said lenticular pattern forming roll and between said first and second belt support rolls; and

 a positioner associated with said third belt
25 support roll for adjusting a length of contact of the hot plastic sheet around a periphery of said rotating lenticular pattern forming roll.

 11. An apparatus according to Claim 6 wherein said second and third belt support rolls are arranged
30 to define a generally horizontal flat portion of said conveyor belt downstream from said rotating lenticular pattern forming roll.

 12. An apparatus according to Claim 1 wherein said conveyor belt has a relatively smooth surface to
35 thereby form a corresponding smooth surface in the plastic sheet.

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13. An apparatus according to Claim 1 wherein said conveyor belt comprises a metal fabric.

14. An apparatus for making a lenticular screen comprising:

5 a rotating lenticular pattern forming roll downstream from an extruder;

a conveyor belt for pressing a hot plastic sheet from the extruder against said lenticular pattern forming roll to form a lenticular pattern in the hot plastic sheet and defining the lenticular screen; and

10 tension adjusting means for adjusting a tension of said conveyor belt to thereby adjust a pressure applied to the hot plastic sheet by said lenticular pattern forming roll and an opposing portion of said conveyor belt.

15 15. An apparatus according to Claim 14 further comprising:

a frame carrying said lenticular pattern forming roll;

20 a first belt support roll carried by said frame and positioned adjacent said lenticular pattern forming roll; and

a second belt support roll carried by said frame and spaced from said first belt support roll.

25 16. An apparatus according to Claim 15 wherein said tension adjusting means comprises a positioner associated with said second belt support roll for adjusting a tension of said conveyor belt.

30 17. An apparatus according to Claim 15 further comprising contact adjusting means cooperating with said conveyor belt for adjusting a length of contact of the hot plastic sheet around a periphery of said rotating lenticular pattern forming roll.

35 18. An apparatus according to Claim 17 wherein said contact adjusting means comprises:

a third belt support roll carried by said frame and positioned adjacent said lenticular pattern forming

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roll and between said first and second belt support rolls; and

5 a positioner associated with said third belt support roll for adjusting a length of contact of the hot plastic sheet around a periphery of said rotating lenticular pattern forming roll.

19. An apparatus according to Claim 14 wherein said conveyor belt comprises a flat portion downstream from said rotating lenticular pattern forming roll and
10 providing a flat surface during cooling of the hot plastic sheet after the lenticular pattern is formed therein.

20. An apparatus according to Claim 19 further comprising cooling means positioned adjacent said flat
15 portion of said conveyor belt for cooling the hot plastic sheet after the lenticular pattern is formed therein.

21. An apparatus according to Claim 14 wherein said lenticular pattern forming roll comprises means
20 for receiving a cooling fluid therein to cool the hot plastic sheet.

22. An apparatus according to Claim 14 further comprising at least one passive sheet guide roll positioned opposite said conveyor and downstream from
25 said lenticular pattern forming roll to guide the hot plastic sheet on said conveyor belt after the lenticular pattern is formed therein and without imparting tension thereto.

23. An apparatus for making a lenticular
30 screen comprising:

a rotating lenticular pattern forming roll downstream from an extruder;

a conveyor belt for pressing a hot plastic sheet from the extruder against said lenticular pattern
35 forming roll to form a lenticular pattern in the hot plastic sheet and define the lenticular screen; and

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contact adjusting means cooperating with said conveyor belt for adjusting a length of contact of the hot plastic sheet around a periphery of said rotating lenticular pattern forming roll.

5 24. An apparatus according to Claim 23 further comprising:

 a frame carrying said lenticular pattern forming roll;

 a first belt support roll carried by said frame
10 and positioned adjacent said lenticular pattern forming roll; and

 a second belt support roll carried by said frame and spaced from said first belt support roll.

 25. An apparatus according to Claim 24 wherein
15 said contact adjusting means comprises:

 a third belt support roll carried by said frame and positioned adjacent said lenticular pattern forming roll and between said first and second belt support rolls; and

20 a positioner associated with said third belt support roll
for adjusting a length of contact of the hot plastic sheet around a periphery of said rotating lenticular pattern forming roll.

25 26. An apparatus according to Claim 24 wherein said conveyor belt comprises a flat portion downstream from said rotating lenticular pattern forming roll and providing a flat surface during cooling of the hot plastic sheet after the lenticular pattern is formed
30 therein.

 27. An apparatus according to Claim 26 further comprising cooling means positioned adjacent said flat portion of said conveyor belt for cooling the hot plastic sheet after the lenticular pattern is formed
35 therein.

 28. An apparatus according to Claim 23 wherein said lenticular pattern forming roll comprises means

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for receiving a cooling fluid therein to cool the hot plastic sheet.

29. An apparatus according to Claim 23 further comprising at least one passive sheet guide roll
5 positioned opposite said conveyor and downstream from said lenticular pattern forming roll to guide the hot plastic sheet on said conveyor belt after the lenticular pattern is formed therein and without imparting tension thereto.

10 30. An apparatus for making a lenticular screen comprising:

a rotating lenticular pattern forming roll downstream from an extruder; and

a conveyor belt for pressing a hot plastic
15 sheet from the extruder against said lenticular pattern forming roll to form a lenticular pattern in the hot plastic sheet and defining the lenticular screen;

said conveyor belt comprising a flat portion downstream from said rotating lenticular pattern
20 forming roll and providing a flat surface during cooling of the hot plastic sheet after the lenticular pattern is formed therein.

31. An apparatus according to Claim 30 further comprising:

25 a frame carrying said lenticular pattern forming roll;

a first belt support roll carried by said frame and positioned adjacent said lenticular pattern forming roll;

30 a second belt support roll carried by said frame and spaced from said first belt support roll; and

a third belt support roll carried by said frame and positioned adjacent said lenticular pattern forming roll and between said first and second belt support
35 rolls to thereby define the flat portion of said conveyor belt downstream from said rotating lenticular pattern forming roll.

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32. An apparatus according to Claim 31 further comprising cooling means positioned adjacent said flat portion of said conveyor belt for cooling the hot plastic sheet after the lenticular pattern is formed
5 therein.

33. An apparatus according to Claim 31 wherein said lenticular pattern forming roll comprises means for receiving a cooling fluid therein to cool the hot plastic sheet.

10 34. An apparatus according to Claim 31 further comprising at least one passive sheet guide roll positioned opposite said conveyor and downstream from said lenticular pattern forming roll to guide the hot plastic sheet on said conveyor belt after the
15 lenticular pattern is formed therein and without imparting tension thereto.

35. An apparatus for making a screen having a predetermined pattern thereon, said apparatus comprising:

20 a rotating pattern forming roll downstream from an extruder; and

a conveyor belt for pressing the hot plastic sheet from the extruder against said pattern forming roll to form a pattern in the hot plastic sheet and
25 defining the lenticular screen.

36. An apparatus according to Claim 35 wherein said pattern forming roll comprises a lenticular pattern forming roll.

37. An apparatus according to Claim 35 further
30 comprising tension adjusting means for adjusting a tension of said conveyor belt to thereby adjust a pressure applied to the hot plastic sheet.

38. An apparatus according to Claim 35 further comprising contact adjusting means cooperating with
35 said conveyor belt for adjusting a length of contact of the hot plastic sheet around a periphery of said rotating pattern forming roll.

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39. An apparatus according to Claim 35 wherein said conveyor belt comprises a flat portion downstream from said rotating pattern forming roll and providing a flat surface during cooling of the hot plastic sheet after the pattern is formed therein.

40. An apparatus according to Claim 39 further comprising cooling means positioned adjacent said flat portion of said conveyor belt for cooling the hot plastic sheet after the pattern is formed therein.

41. An apparatus according to Claim 35 wherein said pattern forming roll comprises means for receiving a cooling fluid therein to cool the hot plastic sheet.

42. An apparatus according to Claim 35 further comprising at least one passive sheet guide roll positioned opposite said conveyor and downstream from said pattern forming roll to guide the hot plastic sheet on said conveyor belt after the pattern is formed therein and without imparting tension thereto.

43. An apparatus according to Claim 35 further comprising:

a frame carrying said pattern forming roll;
a first belt support roll carried by said frame and positioned adjacent said pattern forming roll; and
a second belt support roll carried by said frame and spaced from said first belt support roll.

44. An apparatus according to Claim 43 further comprising a positioner associated with said second belt support roll for adjusting a tension of said conveyor belt.

45. An apparatus according to Claim 43 further comprising:

a third belt support roll carried by said frame and positioned adjacent said pattern forming roll and between said first and second belt support rolls; and
a positioner associated with said third belt support roll for adjusting a length of contact of the

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hot plastic sheet around a periphery of said rotating pattern forming roll.

46. An apparatus according to Claim 45 wherein said second and third belt support rolls are arranged
5 to define a generally horizontal flat portion of said conveyor belt downstream from said rotating pattern forming roll.

47. A method for making a screen having a predetermined pattern thereon, the method comprising
10 the steps of:

extruding a hot plastic sheet;

positioning a rotating pattern forming roll downstream from the extruder; and

using a conveyor belt for pressing the hot
15 plastic sheet from the extruder against the pattern forming roll to form the predetermined pattern in the hot plastic sheet.

48. A method according to Claim 47 wherein the pattern forming roll comprises a lenticular pattern
20 forming roll.

49. A method according to Claim 47 further comprising the step of adjusting a tension of the conveyor belt to thereby adjust a pressure applied to the hot plastic sheet.

25 50. A method according to Claim 47 further comprising the step of adjusting a length of contact of the hot plastic sheet around a periphery of the rotating pattern forming roll.

51. A method according to Claim 47 further
30 comprising the step of configuring the conveyor belt to include a flat portion downstream from the rotating pattern forming roll and providing a flat surface during cooling of the hot plastic sheet after the pattern is formed therein.

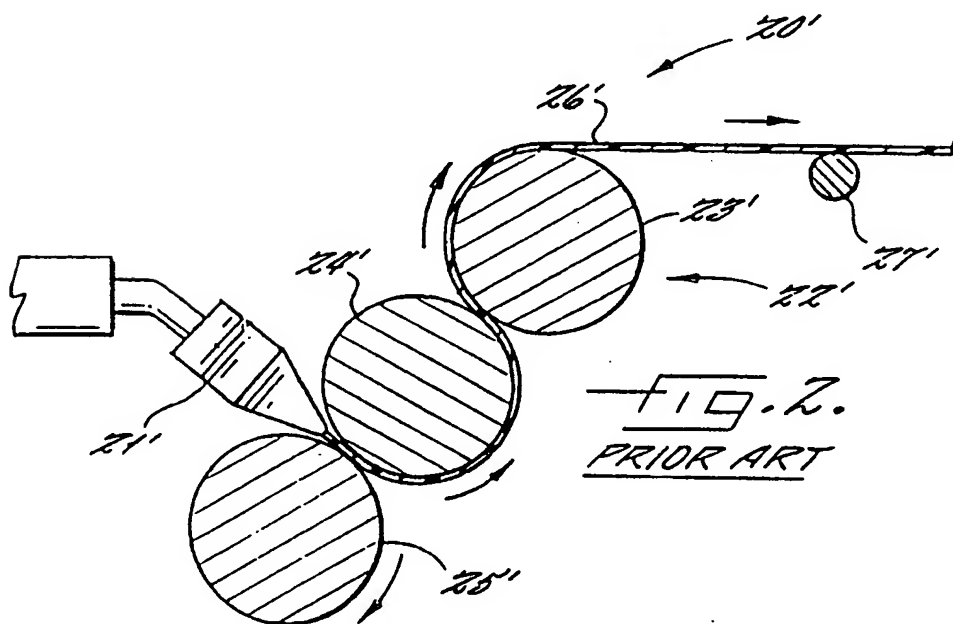
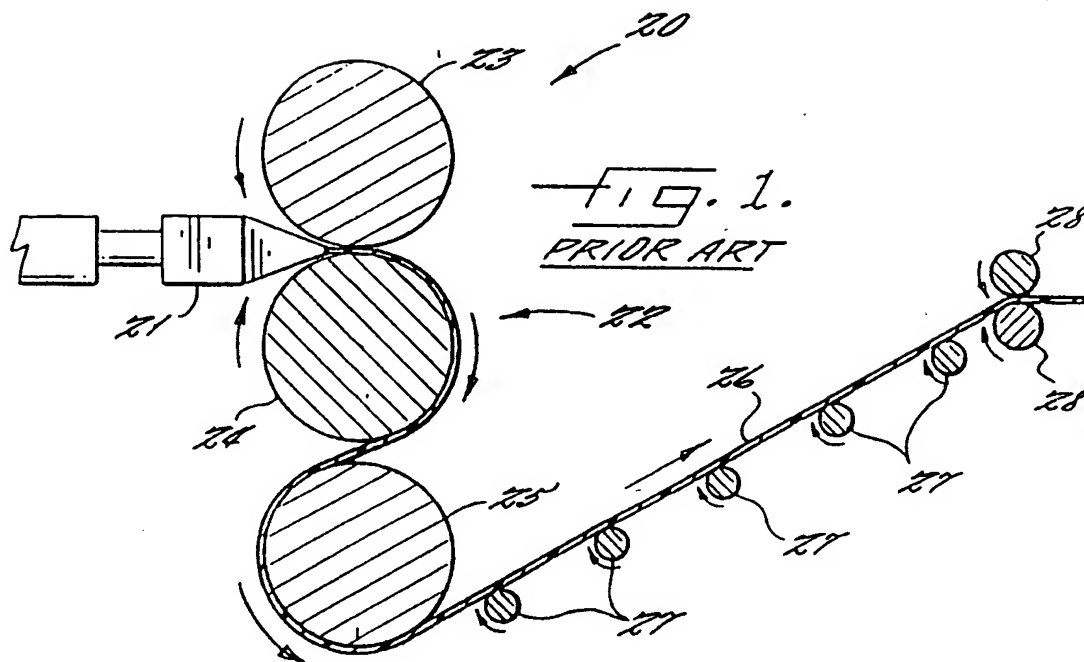
35 52. A method according to Claim 51 further comprising the step of cooling the hot plastic sheet after the pattern is formed therein by positioning at

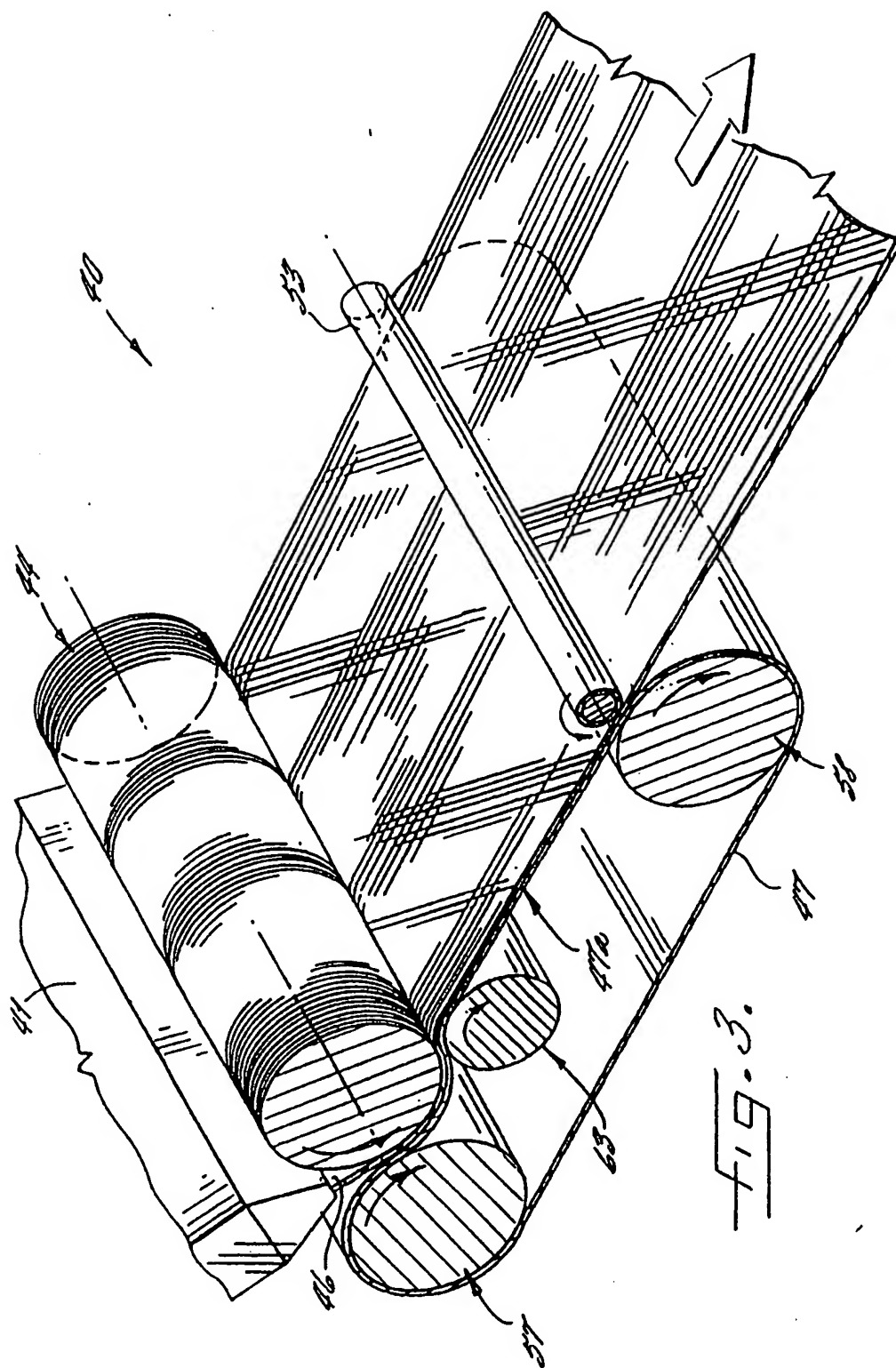
-37-

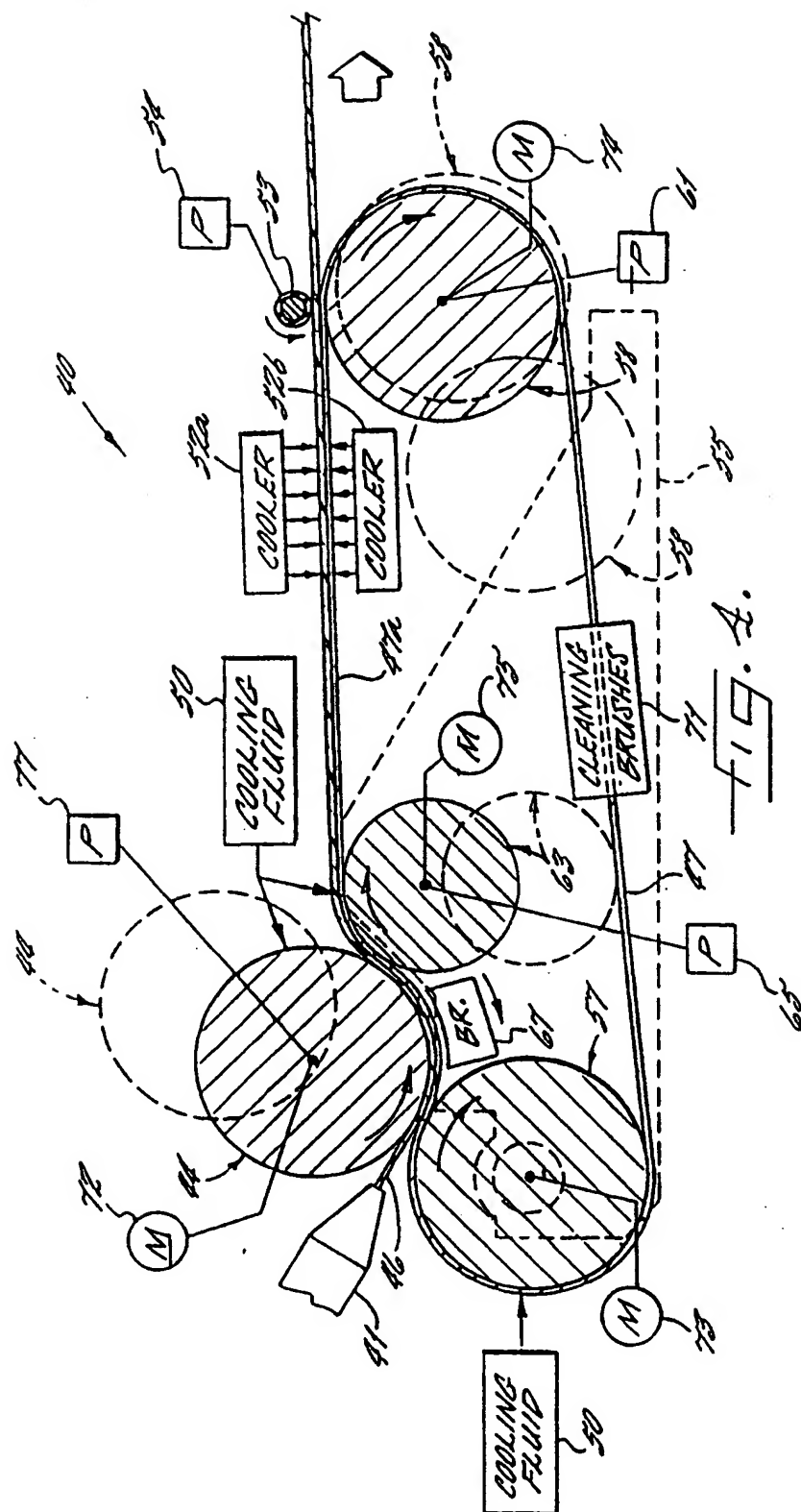
least one cooler adjacent the flat portion of the conveyor belt downstream from the rotating pattern forming roll.

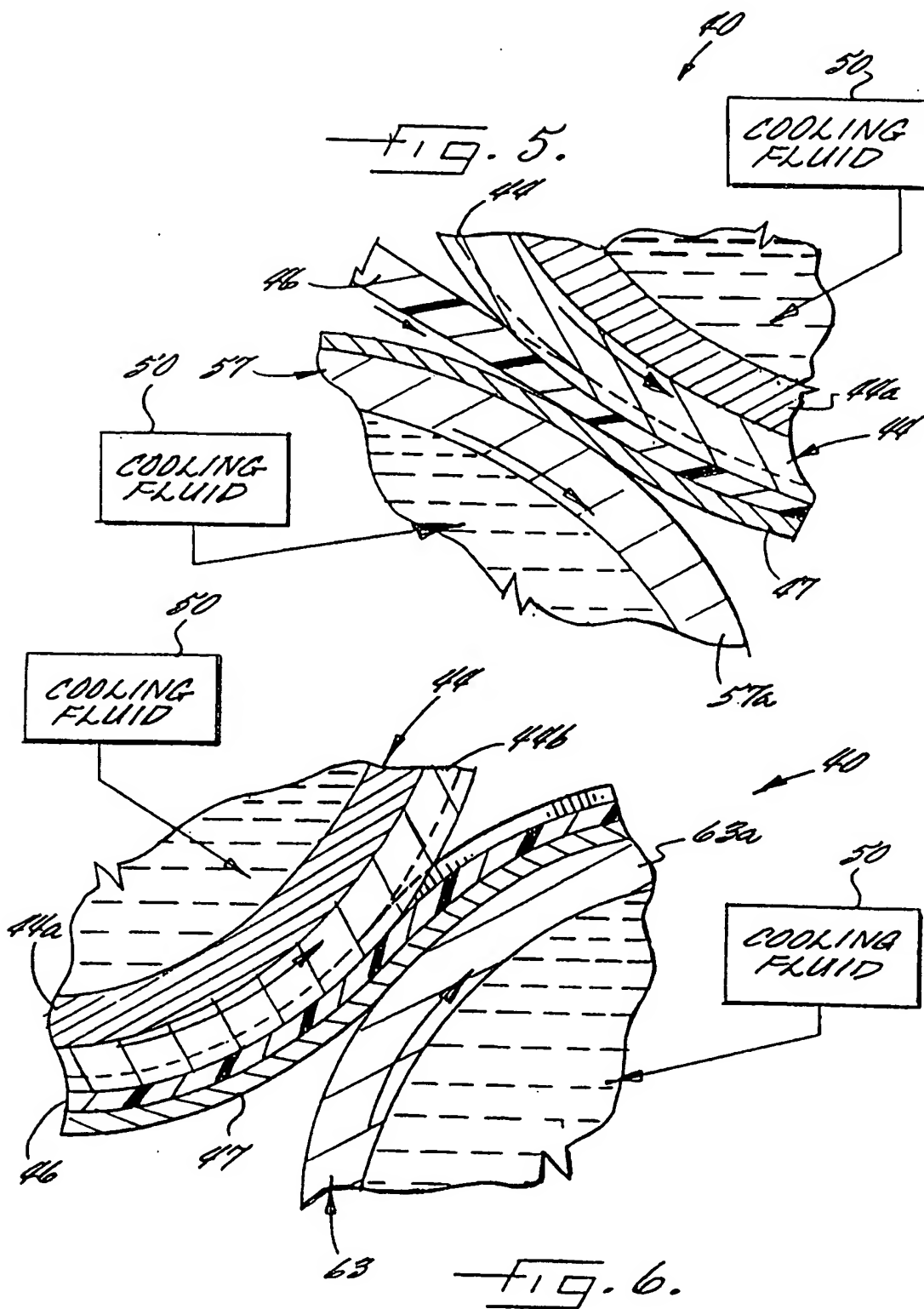
53. A method according to Claim 47 further comprising the step of passing a cooling fluid through the rotating pattern forming roll to cool the hot plastic sheet.

54. A method according to Claim 47 further comprising the step of providing at least one passive sheet guide roll positioned opposite the conveyor and downstream from the pattern forming roll to guide the hot plastic sheet on the conveyor belt after the pattern is formed therein and without imparting tension thereto.

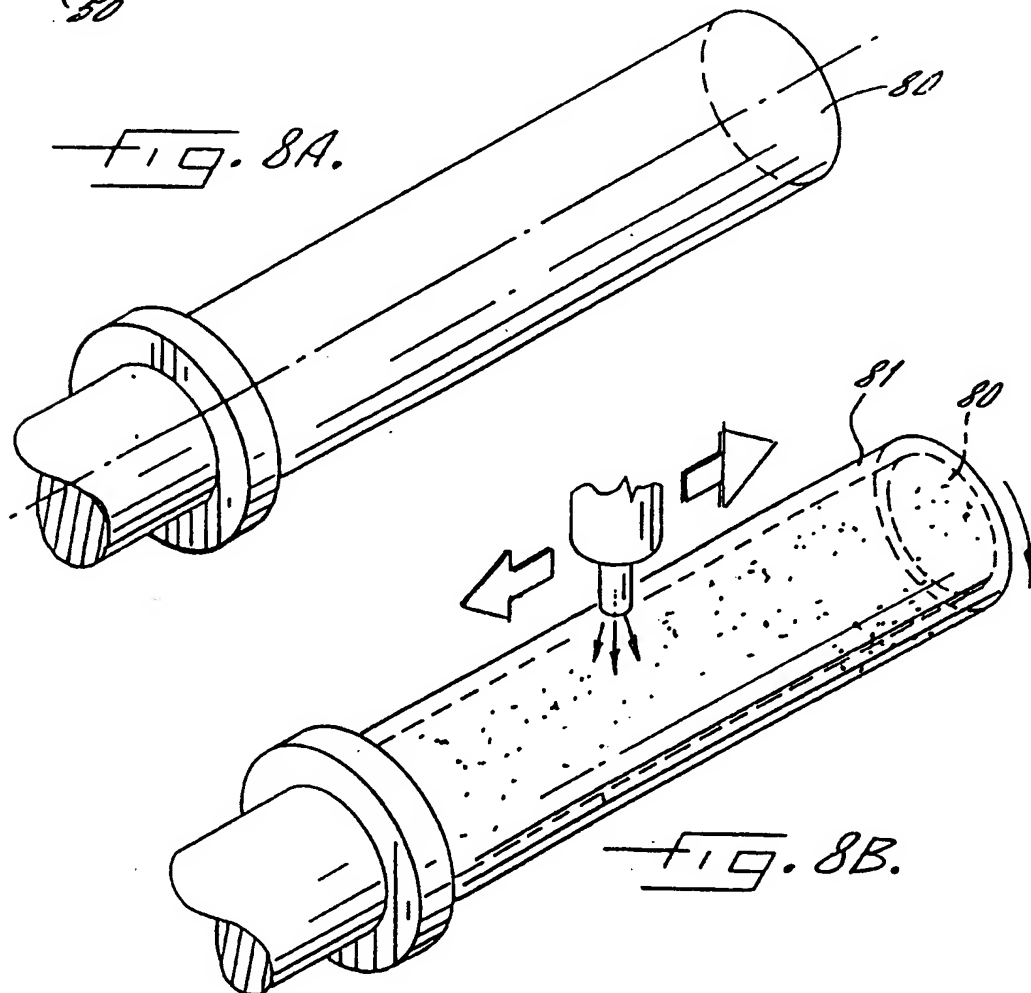
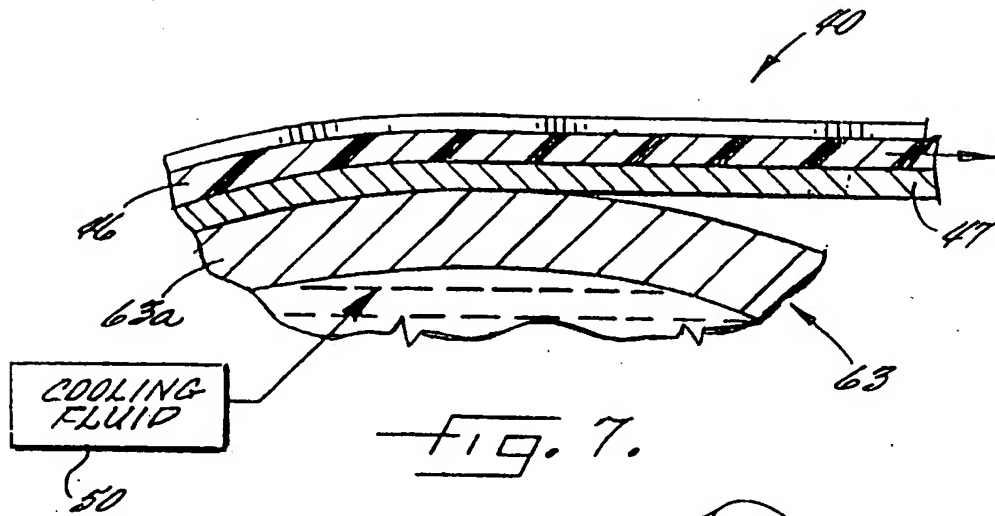


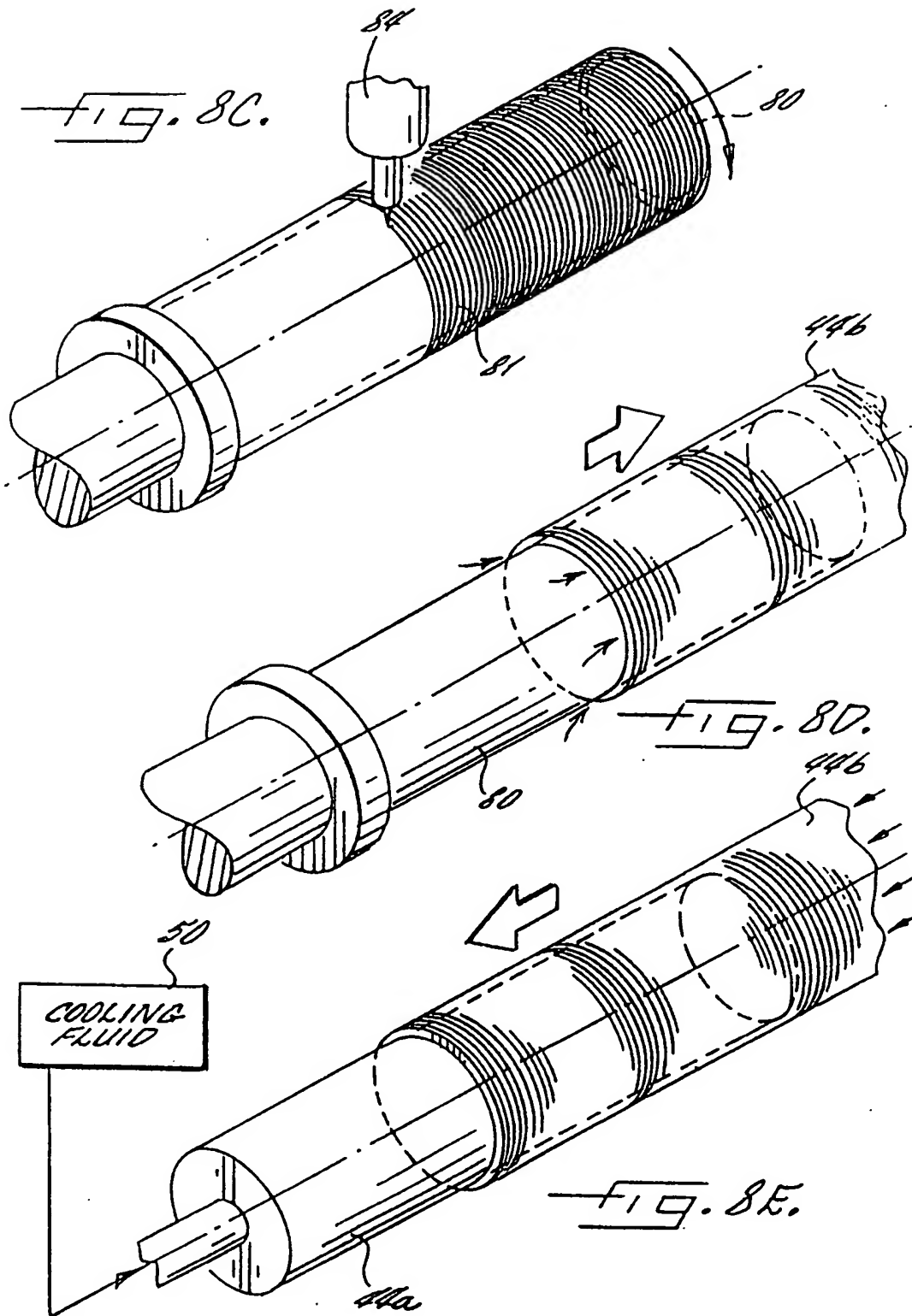




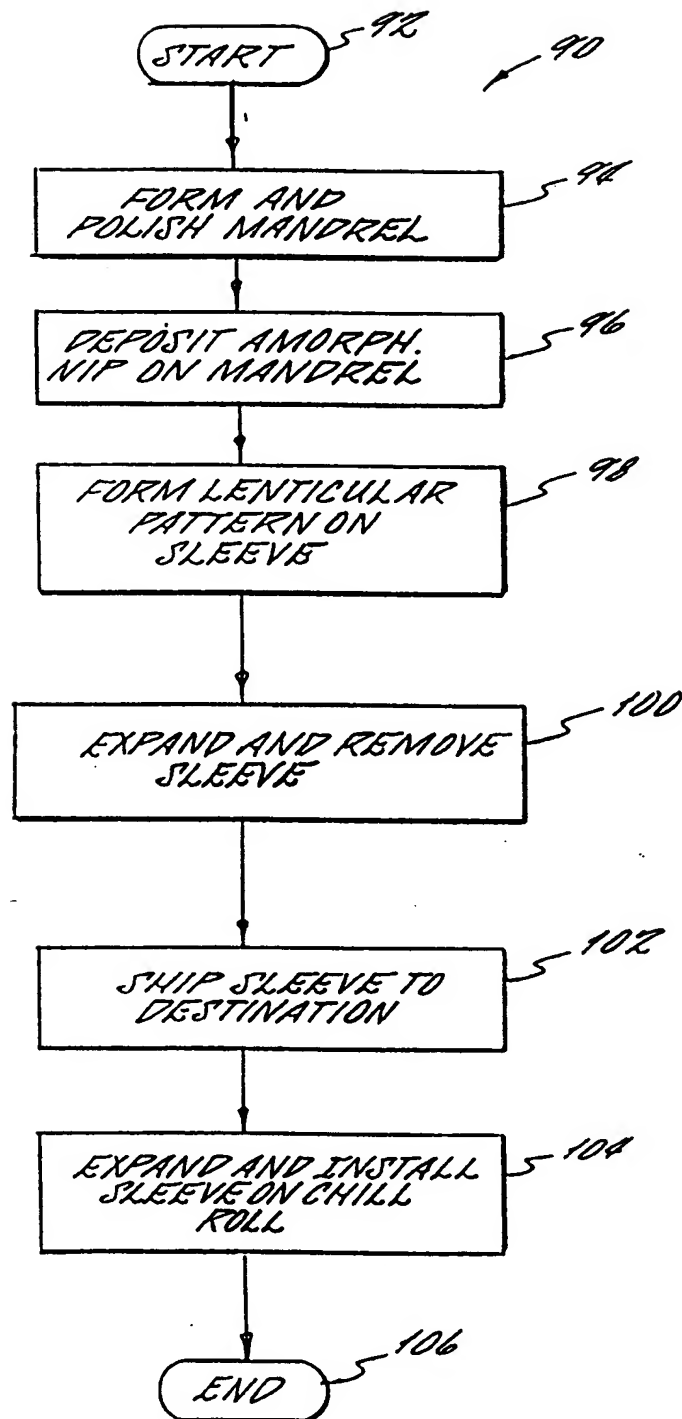


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FIG. 9.

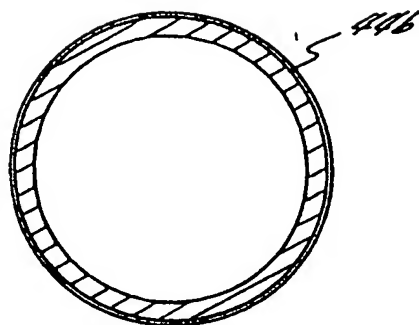


FIG. 10A.

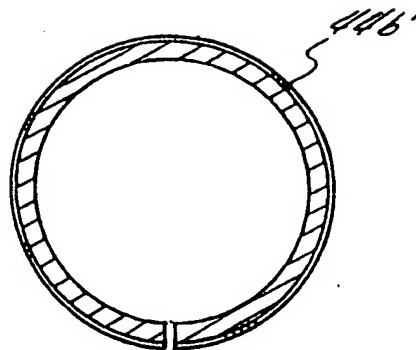


FIG. 10B.

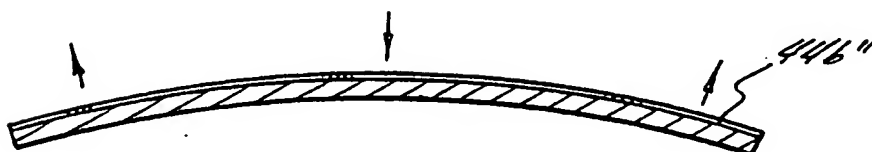


FIG. 10C.



FIG. 10D.

INTERNATIONAL SEARCH REPORT

International Application No.
PCT/US 98/18717

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 B29C47/12 B29C59/04 B29C47/88 G03B35/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 B29C G03B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 193 959 A (LEMELSON JEROME H) 18 March 1980	1-8, 10-12, 14, 15, 17, 19-24, 26-43, 47-54 46
A	see column 4, line 33-49 - column 1, line 29-41; claims 1-6; figures 1-5 ---	
X	WO 96 09154 A (KARSZES WILLIAM M) 28 March 1996	1, 9, 13, 14, 16, 18, 23, 25, 35, 44-47
	see column 7, line 14-37 - column 6, line 5-21; claims 1, 26 --- -/-	

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

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Date of the actual completion of the international search

15 December 1998

Date of mailing of the international search report

22/01/1999

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Dupuis, J-L

INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 98/18717

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